The MINERvA Experimental Effort

Part I - Hardware

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OPOS Seminar

April 13, 2016


New Perspectives 2016
in conjunction with the 49th Fermilab Users Meeting
A conference for young researchers
Fermilab
June 13 -14
See Fermilab from a different point of view
Information and registration: http://orgs.fnal.gov/fspa/new_perspectives
Photo: Mark Kaletka 2015
Fermilab
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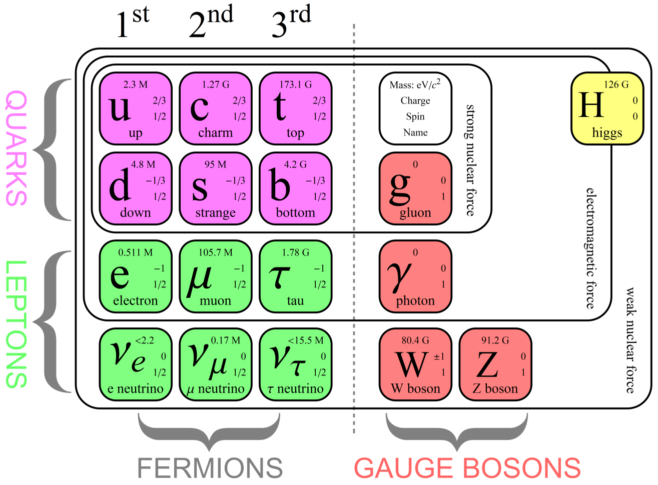
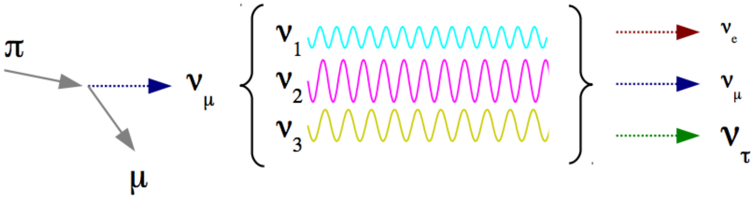
What I'm **not** going to tell you about today

The role of neutrinos in our greater understanding of fundamental physics



Interesting properties of neutrinos



- Oscillation probability:

$$P(\nu_\mu \to \nu_\mu) \approx 1 - \sin^2 2\theta \sin^2\left(\frac{\Delta m^2 L}{E_\nu}\right)$$

(Nature, Experimental)

Neutrinos are very hard to detect compared to other fermions

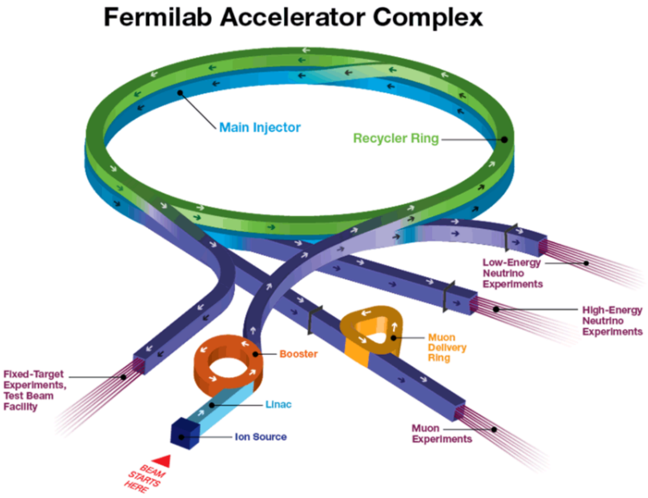
graphic here that shows infrequency of neutrinos interacting

The motivation for MINERvA

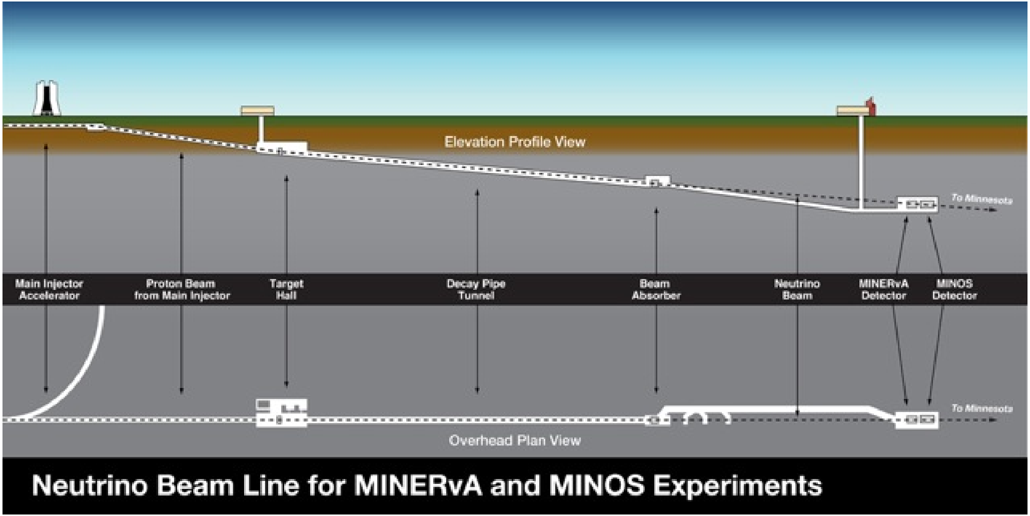
- Experimental measurements have associated errors (uncertainties) that can be divided into two categories: **systematic** and **statistical**
- Measurements of neutrino process are difficult because there are substantial obstacles to reducing both types of uncertainty
- Advances in accelerator technology push our ability to press down **statistical** errors
- Experiments like MINERvA are designed to help us press down **systematic** errors

What I **AM** going to tell you about today

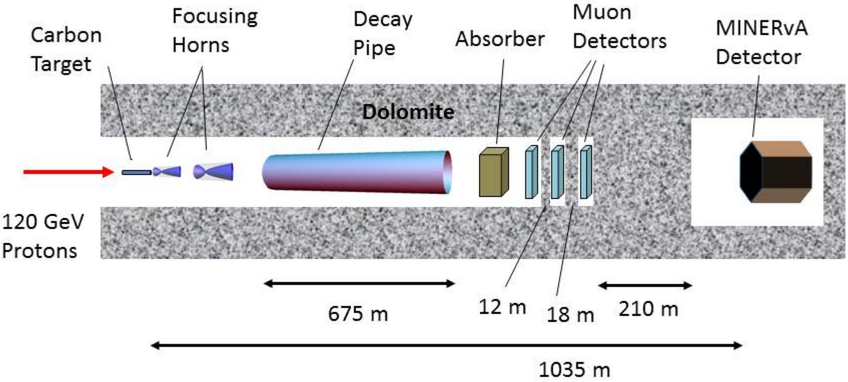
First, you need to produce neutrinos for MINERvA to study

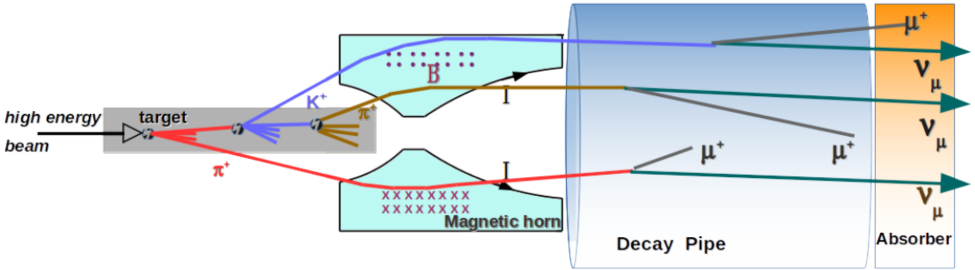


The NuMI beamline takes in protons and spits out neutrinos



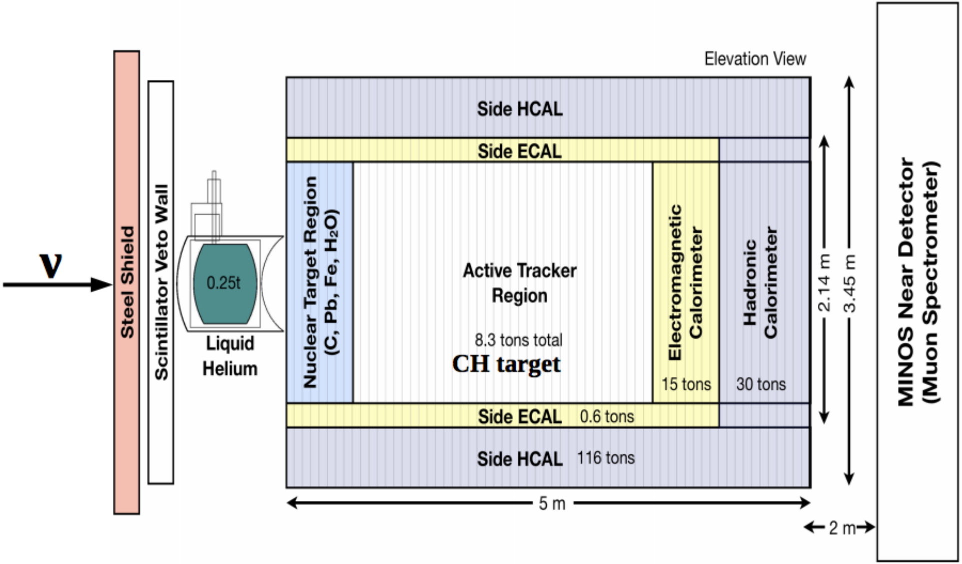
There's lots of cool research that goes into building the most intense source of neutrinos in the world!



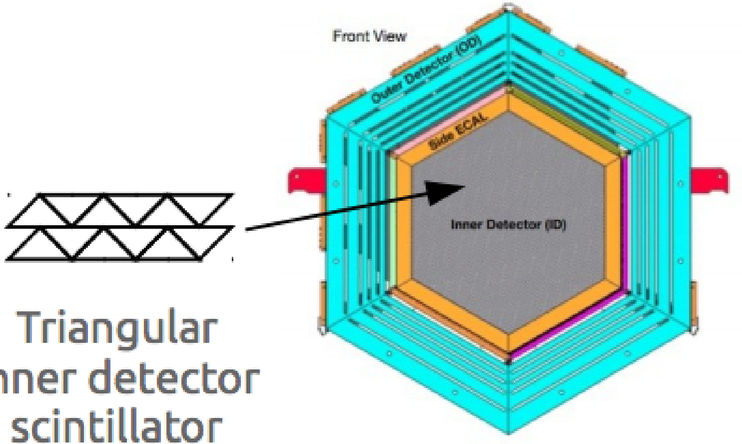


high energy
beam
target
K⁺
π⁺
B
I
Magnetic horn
Decay Pipe
μ⁺
ν μ
Absorber

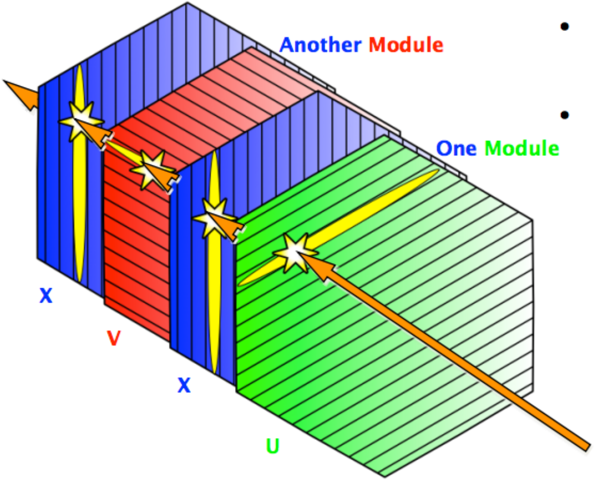
The MINERvA Detector



Nucl. Inst. and Meth. A743 (2014) 130
arXiv:1305.5199

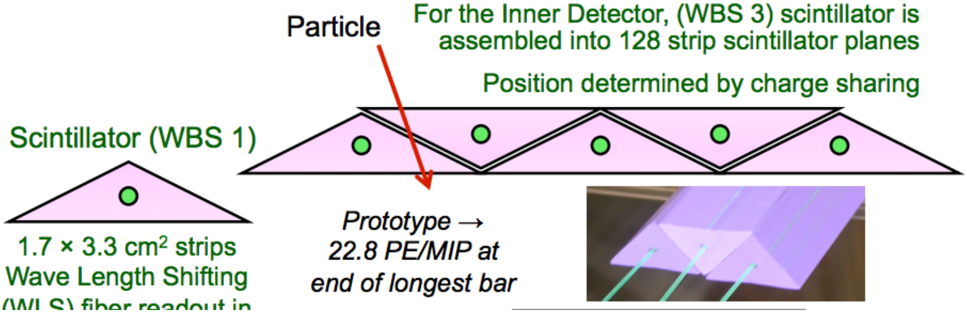


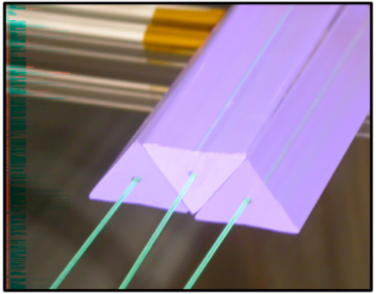
Triangular inner detector scintillator strips

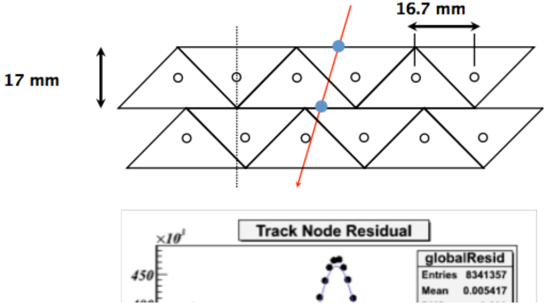

Another Module
One Module
X
V
X
U

•

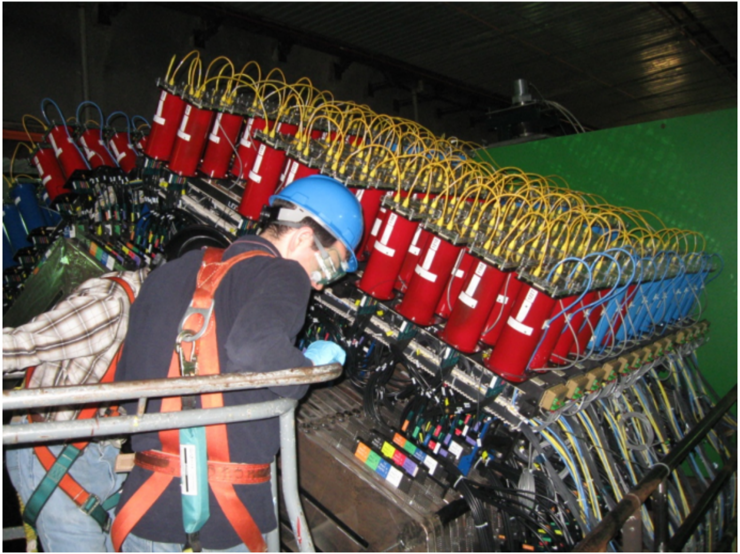
•

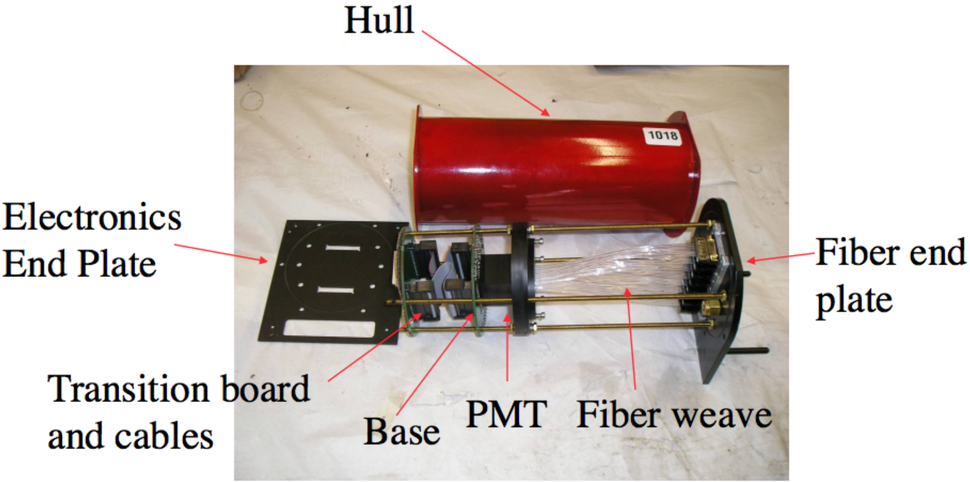

Particle
For the Inner Detector, (WBS 3) scintillator is assembled into 128 strip scintillator planes
Position determined by charge sharing
Scintillator (WBS 1)
1.7 × 3.3 cm² strips
Wave Length Shifting
Prototype →
22.8 PE/MIP at
end of longest bar

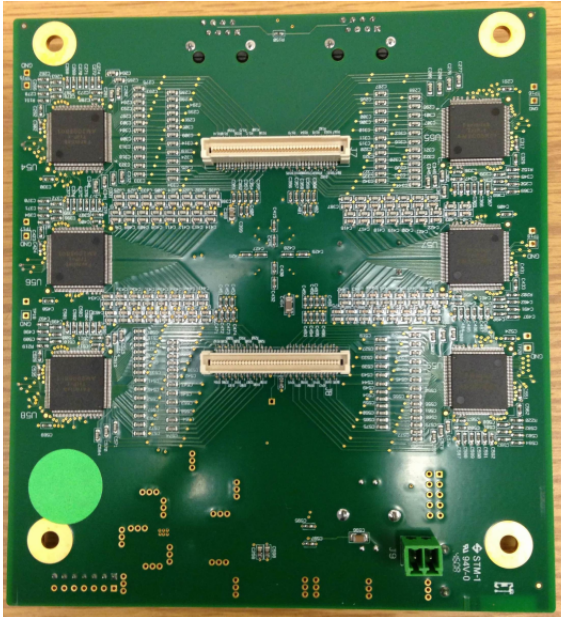




17 mm
16.7 mm
Track Node Residual
×10³
450
globalResid
Entries 8341357
Mean 0.005417




Hull
1018
Electronics
End Plate
Fiber end
plate
Transition board
and cables
Base
PMT
Fiber weave

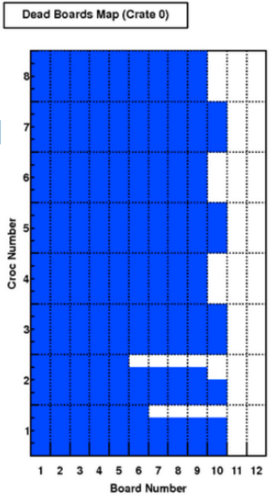


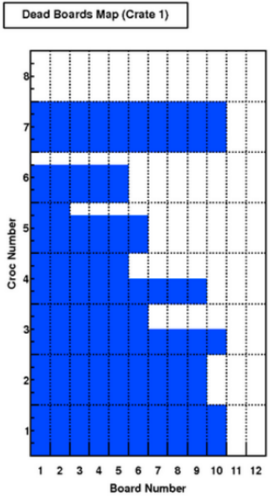

Green lights are good!!

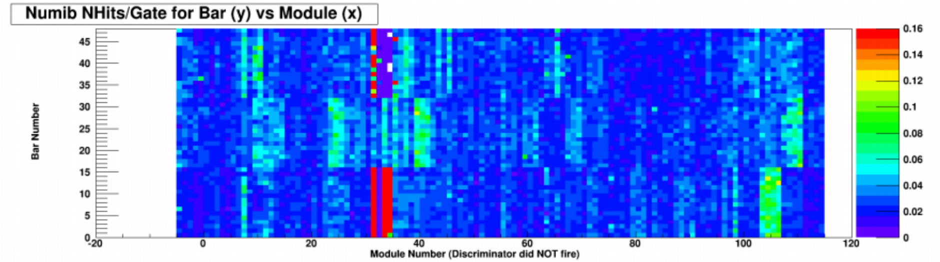
Each CROCE has four chains (0-3) [or four channels (1-4)]

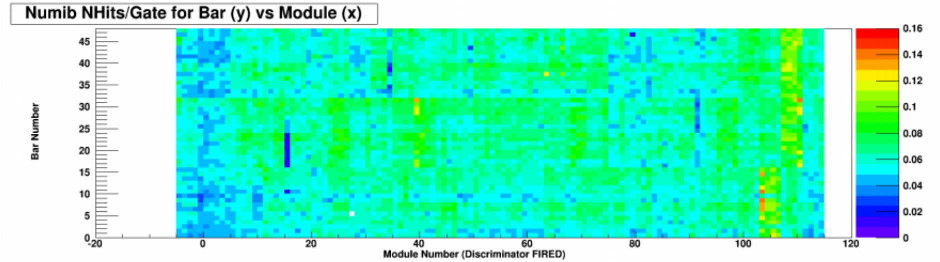
Each chain has anywhere between 5-10 FEBs

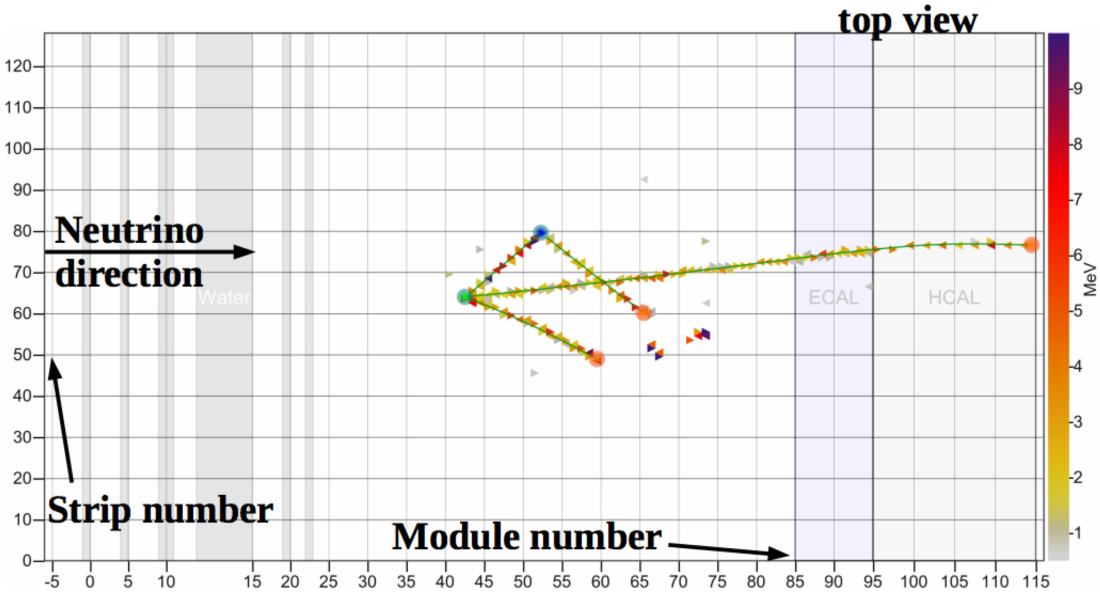
- FEBs 1 & 10 read out the Outer Detector PMTs

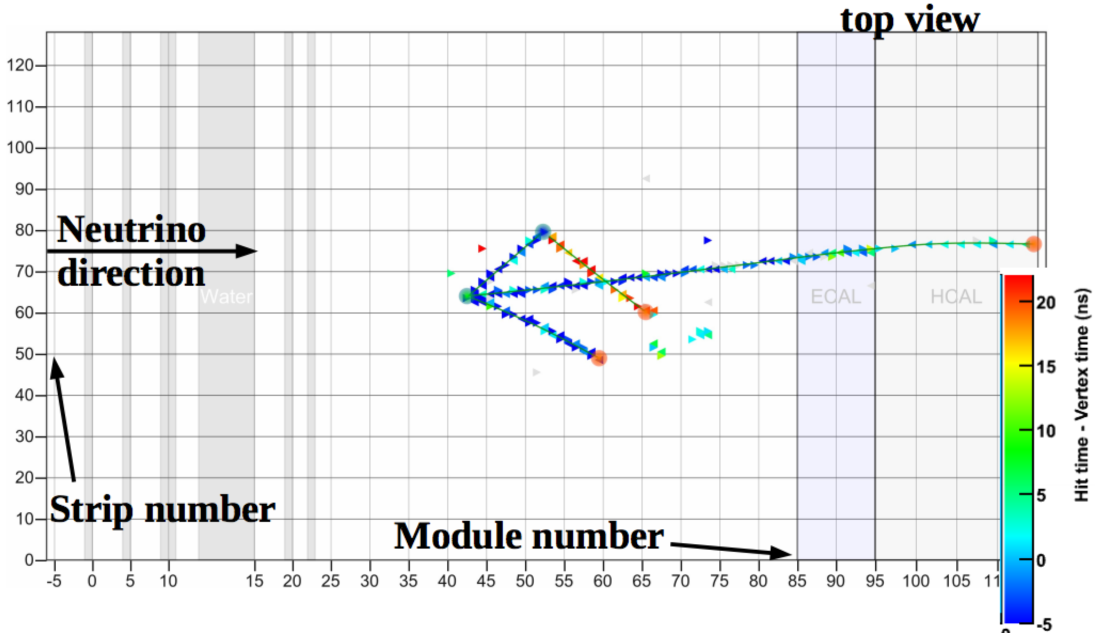


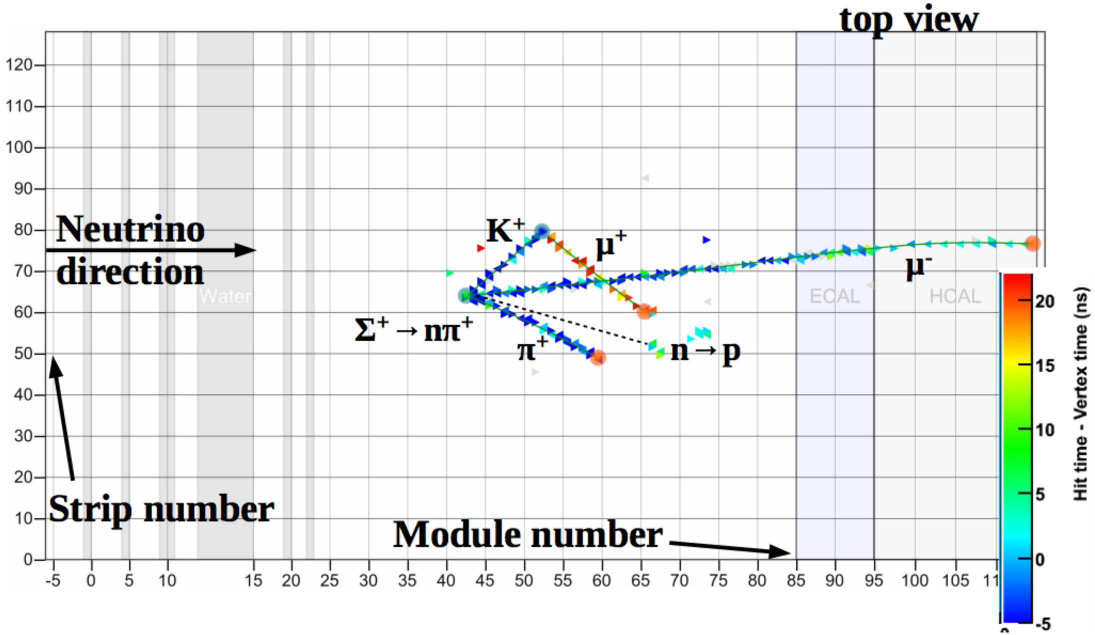



Numib NHits/Gate for Bar (y) vs Module (x)
Bar Number
Module Number (Discriminator did NOT fire)
0
5
10
15
20
25
30
35
40
45
-20
0
20
40
60
80
100
120
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16


Numib NHits/Gate for Bar (y) vs Module (x)
Bar Number
Module Number (Discriminator FIRED)
0
5
10
15
20
25
30
35
40
45
-20
0
20
40
60
80
100
120
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16


top view
Neutrino direction
Strip number
Module number
Water
ECAL
HCAL
MeV

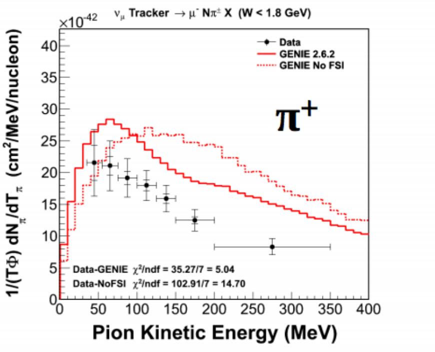

top view
Neutrino direction
Strip number
Module number
Water
ECAL
HCAL
Hit time - Vertex time (ns)
120
110
100
90
80
70
60
50
40
30
20
10
0
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
20
15
10
5
0
-5


top view
Neutrino
direction
Water
ECAL
HCAL
Strip number
Module number
K^+
μ^+
μ^-
$\Sigma^+ \rightarrow n\pi^+$
π^+
$n \rightarrow p$
Hit time - Vertex time (ns)

More of what I'm **not** going to tell you about today

The physics results of MINERvA

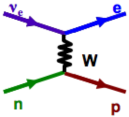
ν_μ CC MINERvA data



Phys. Rev. D 92, 092008 (2015)
Wine & Cheese 7 February 2014

K^+

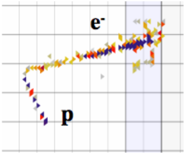
Today!

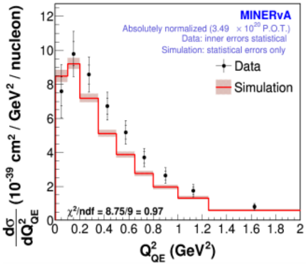


Electron neutrino CCQE

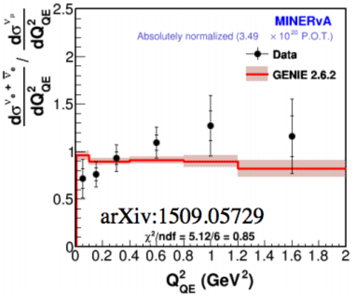
ν_e CCQE is oscillation signal, but almost no cross section data.

Can we trust $\nu_\mu \rightarrow \nu_e$ cross section universality in complex nuclei?



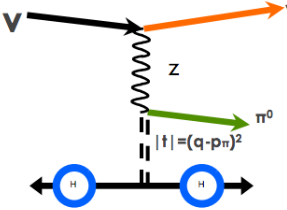


Measured cross sections consistent with GENIE model (assumes charged lepton mass only difference between XS) at 1σ (~15-20% uncertainties)

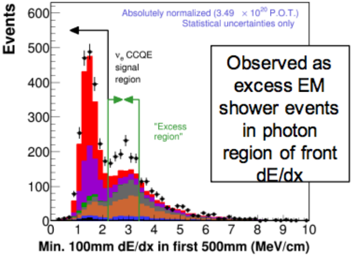


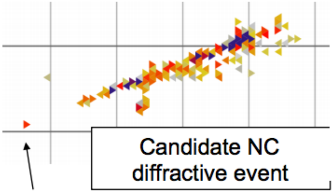
ν_e/ν_μ difference not significant (~1σ). Good enough for current expts. but shape may need further investigation for future high-precision oscillation results

NC diffractive scattering from H

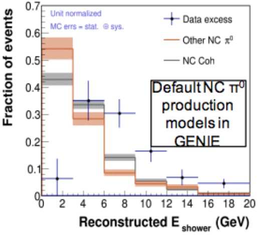


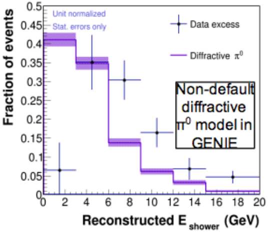
Analogous to NC coherent production. Potential background for ν_e appearance. Not in default generator models.





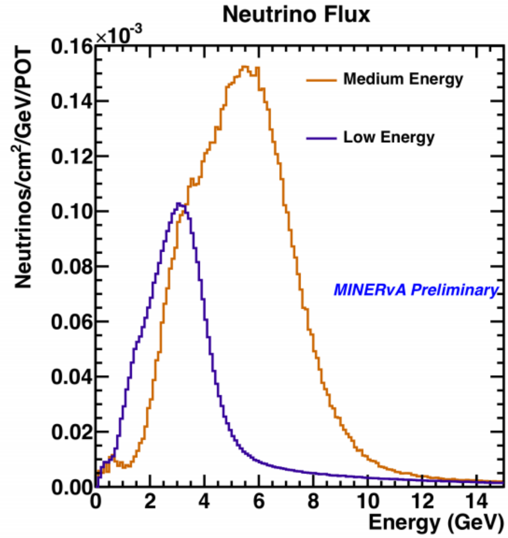
Probable recoil from proton





Observed energy behavior is very different from any other NC π^0 production models

The future of MINERvA Analysis



A future upgrade to MINERvA

Future plans for studying "big picture" neutrino properties